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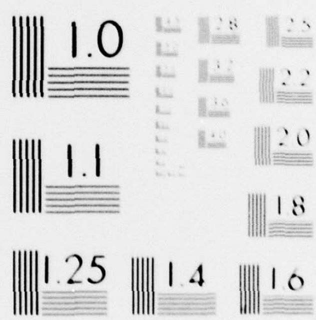

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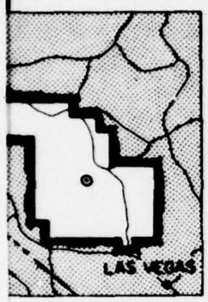
OPERATION PLUMBBOB

NEVADA TEST SITE

MAY-OCTOBER 1957



Project 37.4

MEASUREMENT AND PERMANENT RECORDING OF FAST NEUTRONS BY EFFECTS ON GERMANIUM DOSIMETERS

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Operation PLUMBBOB Preliminary Report

Project 37.4

MEASUREMENT AND PERMANENT RECORDING OF FAST NEUTRONS BY EFFECTS ON GERMANIUM DOSIMETERS

By

B. Cassen and H. C. Gass

Approved by: K. H. Larson, Director, Program 37

Approved by: R. L. Corsbie, Director, Civil Effects Test Group

Atomic Energy Project
University of California
at Los Angeles

September 1957

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ABSTRACT

Laboratory and field experiments relative to the use of semiconductor fast-neutron dosimeters which were pursued on a small scale in Operation Upshot-Knothole and Operation Teapot were continued. Considerable improvements in methodology and procedures of dosimeter preparation leading to increased accuracy, reproducibility and sensitivity were obtained in interim laboratory studies. Results obtained during Operation Plumbbob that take advantage of these improvements are reported.

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Chapter 1

INTRODUCTION

1.1 BACKGROUND

Discovery of changes in the electrical conductivity of single-crystal germanium produced by exposure to a fast-neutron flux was the result of investigations by Lark-Horowitz and collaborators at Oak Ridge.[1] First attempts to use this phenomenon for dosimetric applications were made by the authors in a preliminary study[2] at Operation Upshot-Knothole in 1953. Between 1953 and 1955, extensive improvement was obtained in small-scale research and development at the UCLA Atomic Energy Project (UCLA-AEP). Participation was undertaken in Operation Teapot,[3] and relatively excellent results were obtained with one purchased batch of germanium. At the same time results were obtained with material from other sources of supply which were very difficult to interpret. Variable surface conductivity conditions were also encountered. It was then realized that material could not be satisfactorily specified for purchase and that probably subspectroscopic amounts of impurities could radically change the response characteristics of the single-crystal germanium to fast neutrons. During 1956, the Biophysics Department of the UCLA School of Medicine, in cooperation with the UCLA-AEP, received a grant from the Air Force to study the preparation of single-crystal germanium so that it could be grown to have reproducible and specifiable properties with respect to its response to fast neutrons. A zone-melt ingot purification and crystal-growing furnace was set up, and many melts were made under a wide variety of conditions.[4] It was found that any type of previously observed response, e.g., that of the General Electric Co. (GE) and Hughes batches found during Operation Teapot,[3] could be reproduced by control of minute amounts of certain additives such as metallic indium. Several such crystal ingots were grown in preparation for Operation Plumbbob. It has not yet been determined whether or not the prepared dosimeters are optimum for field measurements, but they are believed to be better than those previously used.

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The basic findings of this interim effort on the preparation of germanium suitable for dosimetry are shown in Fig. 1.1. The dose-response curve of the material most highly purified by zone melt is represented diagrammatically by curve A. It had the highest slope and the crossover point (a) fell in the range of 100 to 150 rep. The relative behavior of other batches is shown by curves B, C and D. Material prepared by GE[3] followed a response such as D, with a crossover point (d) in the region of 18,000 rep. However, the initial slope in the negative direction, indicated by the dotted line F, was higher than the slope of A above its respective crossover point. For this reason the GE material seemed to give indications of some of the internal shelter doses on shot Apple I in the dose range of 25 rep.[3]

Up to the present time, numerous unsuccessful attempts have been made to add controlled amounts of indium to a material of characteristic response A in order to shift its starting point beyond the crossover (a) shown on the abscissa of Fig. 1.1. Different parts of the same ingot have been shown to acquire different responses, and much of the ingot was usually unusable because of the resultant low resistivity of the dosimeters. Preliminary tests indicated that a practical procedure for application to the problems of Operation Plumbbob entailed a preexposure of dosimeters made of type A material to about 2000 to 5000 rep., e.g., by placing a batch at a selected distance from a shot earlier than the shots on which the dosimeters would be used for measurement purposes. The procedure would produce the "bump-over" desired, with the associated disadvantage that the dosimeters would require recalibration at the UCLA-AEP to establish their initial resistances prior to field use.

1.2 OBJECTIVES

The main objective of the present operation was to determine whether or not the interim improvements and increased knowledge of the behavior of germanium dosimeters, as described in Sec. 1.1, could be utilized to obtain increased accuracy and sensitivity of fast-neutron dosage measurements made in the region of a nuclear detonation. A supplementary objective was to determine whether or not the higher initial negative slope of the type D material (Fig. 1.1) could be used to obtain greater sensitivity for measurement of fast-neutron penetration of personnel shelters close to GZ.

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1. Nucleon Irradiated Semiconductors, Reading Conference, Purdue University Special Report, July, 1950.

2. B. Cassen, H. Gass and J. Nuding, Measurement of Fast Neutrons by Effects on Semiconductors, Operation Upshot-Knothole Report WT-803, September, 1953.

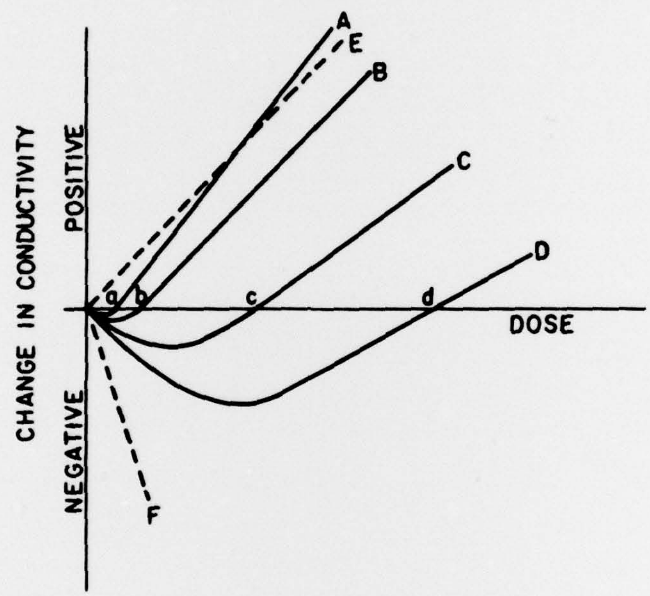

Fig. 1.1—Dose-response curves for various purities of germanium.

[redacted]

3. B. Cassen, H. Gass, T. Crough, W. A. Smith, Jr., and J. Moyer, Measurement and Permanent Recording of Fast Neutrons by Effects on Semiconductors, Operation Teapot Report WT-1170, March, 1957.

4. B. Cassen, V. Burkig and W. A. Selle, Development of a Germanium Crystal Dosimeter, School of Aviation Medicine, USAF, Report No. 57-90, May, 1957.

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Chapter 2

METHODS

2.1 SHOT PARTICIPATION

After discussion with other dosimetric groups participating in Operation Plumbbob it was agreed that maximum information on the performance of the single-crystal germanium fast-neutron dosimeters could be obtained with minimum effort and expense through cooperative participation. Germanium dosimeter stations similar to those used at Operation Teapot[1] were placed adjacent to neutron and gamma-dosimetry stations surveyed and established by Projects 39.1 and 39.5 (ITR-1500 and ITR-1504). In this manner, resultant measurements could be directly compared with those made by other techniques. Participation of this nature was undertaken on shots Stokes, Doppler, Franklin Prime, Smoky, Fizeau and Laplace. On shot Smoky certain types of germanium fast-neutron dosimeters were placed in shelters in cooperation with Project 39.1 and returned to Project 37.4 for reading after their postshot recovery.

2.2 INSTRUMENTATION

The laboratory instrumentation and field methodology and instrumentation were not significantly different from Operation Teapot[1] and the references given in it.

2.3 FIELD PROCEDURES

Germanium dosimeters were prepared for field experiments by inserting four dosimeters into an 8-in. length of 52S aluminum tubing with a 0.375-in. outside diameter and a 0.049-in. wall. The aluminum tube was swaged closed at one end, and after it was filled, the open end was closed with glass-fiber-reinforced scotch tape. Two of the filled tubes were wrapped in aluminum foil and placed within a 12-in. long thin-wall aluminum tube of 1-in. outside diameter. Both ends were

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sealed with rubber stoppers to prevent infiltration of radioactive contaminants.

The stoppered units were fastened to standard angle-iron fence posts, 1.25 in. by 1.25 in. by 6 ft., which were driven into the ground so that the apex of the angle faced the direction of the on-coming shock front. The post was slanted so that the major dimension of the dosimeter unit was approximately perpendicular to the radial line from the point of detonation. The tubular units were fastened to the stake in its protected included angle and were held in position with standard fiber-glass-reinforced tape. The stakes and tubes were then completely covered with heavy-duty aluminum foil to act as a heat-flash shield. Previous operations had shown that even at stations set up near the base of towers this type of flash shield successfully prevented severe burning of the stakes and attached materials.

These units were located along the surveyed lines of Projects 39.1 and 39.5 near stations established by those projects as well as those of Projects 39.9 and 37.5. Slant distances were computed from information supplied by the former two groups. Two to four of the stoppered units were used at each of the close-in stations and one or two at the more distant stations. On higher yield shots stations were generally located at 600, 700, 800, 900, 1000, 1100, 1200, 1250, 1300, 1400, 1500, 1750 and 2000 yards from GZ. On smaller yield shots the distances were usually 500, 600, 700, 800, 900, 1000, 1250 and 1500 yards.

Postshot recoveries were customarily made on D+2 day, since the resistance changes in the dosimeters produced by fast-neutron exposure are relatively permanent. This allows a later recovery after the areas have become more accessible from a Rad-Safe standpoint. In some cases recoveries were made much later without apparent effect on the dosimeters. If on recovery any tubes showed radioactive contamination beyond acceptable limits, the rubber stoppers were removed and discarded with the outside tube at the recovery site, and the non-contaminated inner containers were transported back to the Mercury laboratory.

After each shot recovered dosimeters were recorded and sorted into special holders in which they were transported to the UCLA-AEP for cold-bath measurements of resistivity changes.

Preliminary results obtained on shot Stokes indicated that the amount of indium in most of the dosimeters was not constant nor sufficient enough to yield linear responses in the lower dosage range. This suggested that instead of depending on exact indium-content control, the dosimeters should be preirradiated by exposure to about 2000 rep on a shot prior to the one which they would document. Therefore on shot Doppler 250 dosimeters were placed in a steel pipe at a distance chosen to receive approximately 2000 rep. These dosimeters were then

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sent back to the UCLA-AEP for establishment of a new preshot resistance value. The chosen predose proved to be optimum, and 99 percent of the instruments showed a slight increase in conductivity, indicating that they had been dosed just beyond their crossover points as explained in Sec. 1.1. These dosimeters were used on shot Franklin Prime, and a new batch was preirradiated by Franklin Prime for use on later tests.

REFERENCES

1. B. Cassen, H. Gass, T. Crough, W. A. Smith, Jr., and J. Moyer, Measurement and Permanent Recording of Fast Neutrons by Effects on Semiconductors, Operation Teapot Report WT-1170, March, 1957.

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Chapter 3

RESULTS

3.1 INTERIM SUMMARY

The results of laboratory measurement of exposed dosimeters showed that the expected improvement in accuracy and sensitivity was not obtained. This was traced back to laboratory errors in pre-measurement. The results, however, have about the same quality as those obtained during Teapot.[1] Table 3.1 is a summary of some of the measurements obtained. They and additional measurements, which are harder to definitely interpret at the present time, such as shelter measurements on shot Smoky, will be exhaustively analyzed in the final report.

The units of ΔC in Table 3.1 are micromhos per inch as used previously in WT-1170. In WT-1170 the symbol $\Delta\sigma$ was used instead of ΔC. They are equivalent.

REFERENCES:

1. B. Cassen, H. Gass, T. Crough, W. A. Smith, Jr., and J. Moyer, Measurement and Permanent Recording of Fast Neutrons by Effects on Semiconductors, Operation Teapot Report WT-1170, March, 1957.

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Table 3.1 - SUMMARY OF RESULTS

Shot	Slant Distance in Feet	No. of Dosi-meters	Average △C
Stokes	2343	10	14,345
		7	14,481
	2581	15	12,405
	2848	13	7,157
	3044	9	3,891
	3354	10	641
Doppler	2121	16	16,308
	2343	10	8,662
		11	10,138
		15	10,622
	2581	4	6,232
		16	7,360
	2704	21	6,570
	2848	17	3,955
	3044	7	2,570
		4	2,948
	3354	8	1,494
		4	1,519
Laplace	1677	8	5,162
	1950	7	3,204
	2226	7	1,662
Franklin Prime	1677	6	13,900
		3	15,605
		11	14,151
		6	13,100
	1951	4	8,208
		10	7,962
		8	7,770
	2229	4	4,069
		14	4,215
		5	4,818
		4	4,545
		4	3,993
	2343	4	3,007
		4	3,213
		4	3,338
		4	3,274
	2514	7	2,568
		4	2,588
		3	2,137
	2811	4	1,877
		4	1,276
	3093	3	1,184
		4	846
Fizeau	1869	10	9,496
	2173	3	8,709
	2735	4	5,979
	3039	8	2,250
		9	2,165
	3633	10	360

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